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JOURNAL OF THE AMERICAN ROCKET SOCIETY

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Reaction Propulsion Research In Poland

Investigation Of Rocket Power As Applied To Aviation

By Z. L. KRZYWOBLOCKI

Rocket and jet propulsion investigation as applied to aviation carried out by the author was divided into two parts: theoretical and experimental. The first was started early in 1933 and proceeded in three directions.

(a) Investigation referring to rocket and jet propulsion of the whole aeroplane.

(b) Investigation referring to auxiliary rocket and jet propulsion during takeoff and landing.

(c) Investigation referring to rocket projectiles launched from the ground or from the aeroplane in the air.

As the result of these theoretical considerations, referring to group (a), two papers appeared (ref. 1, 2). The purpose of those investigations was to find out the optimum height of flight of a rocket propulsion aeroplane for the given kind of propulsive material, and the possibility of applying reaction propulsion to various types of aeroplanes. The conclusions drawn were as follows:

(1) The optimum density of air for the flight is inversely proportional to the square of velocity of exhaust gases.

(2) Taking into account the development of aviation technics of today, it does not look probable that reaction propulsion might be applied to transportation aeroplanes and bombers.

(3) It is quite possible that in the near future this type of propulsion will find an application to fighter and pursuit types of aeroplanes.

The purpose of the investigations of group (b) was to calculate the distance of takeoff and landing with the application of powder rockets to land

gliders, water gliders towed by hydroplanes or boats, landplanes and hydroplanes. The results of these calculations were published in Poland and in France (ref. 3, 4, 5), and in the last year in the United States (ref. 6). These were the first calculations of assisted takeoff and landing to be published. From the calculations the following conclusions were drawn:

Gliders With Skids

(1) About 24 lbs. of black powder (or 1.5 lbs. of gasoline) are needed to assist the takeoff of a 600 lb. motor-glider from a level hilltop.

(2) About 19.5 lbs. of black powder (or 1.25 lbs. of gasoline) are needed to assist the takeoff of a 400 lb. glider from a level hilltop.

(3) For the takeoff of a 440 lb. glider on an inclined hilltop, about 9 lbs. of black powder (or 0.56 lbs. of gasoline) are needed.

(4) After takeoff, for a gain of altitude of 1,650 ft. for the 440 lb. glider, 160 lbs. of black powder (or 10 lbs. of gasoline) are needed.

(5) For horizontal flight from thermal to thermal, a 440 lb. glider will travel a distance of 3,270 ft. with a charge of $10\frac{1}{2}$ lbs. of black powder (or 0.66 lbs. of gasoline).

(6) To cut the sinking speed in half while in free flight, a 440 lb. glider will require 6 lbs. of black powder (or 0.39 lbs. of gasoline).

(7) The use of rocket or jet propulsion blends in very well with the streamline shape of a glider and will not spoil its aerodynamic characteristics.

Water Gliders

(1) About 32 lbs. of black powder are needed to cut the distance of take-off of a water glider towed by a seaplane to 30% of the distance of take-off of the same water glider towed by a seaplane without use of rockets (rockets in seaplane or sea glider).

(2) About 14.6 lbs. of black powder are needed to cut the distance of take-off of a 750 lb. two place sea glider towed by a 300 h.p. motorboat to 45% of the distance of takeoff of the same combination without rockets (rockets in sea glider).

Landplanes

(1) By use of powder rockets it is possible to shorten takeoff by 30 to 50%, the landing run by about 37%. The calculations showed that powder rockets are not large.

(2) It is characteristic that at greater overloading of an aeroplane the powder rockets are more effective; i.e., the percentage in shortening takeoff is greater when the aeroplane is heavier.

(3) It is very doubtful whether powder rockets may be used in case of takeoff when clearing obstacle since the volume of powder is too great.

Seaplanes

(1) The use of powder rockets permits shortening the length and time of takeoff by 40 to 50%. The weight of rockets is not great.

(2) In some cases, e.g., takeoff of an overloaded seaplane, the length of takeoff may be so great as to be feasible only with rocket or jet propulsion or some such device.

The purpose of investigations carried out in group (c) was twofold:

(1) General considerations of the possibility of using rocket or jet projectiles launched from the ground or from an aeroplane in the air, possible

development of winged rocket bombs, rocket torpedoes, etc. The results of these investigations were published in Poland and later in the United States and Canada (ref. 7, 8, 9).

(2) The calculation of the range of a wing-bomb and rocket torpedo, the influence of the kind of propulsive material and the height of flight of an aeroplane launching the wing-bomb on the range. These calculations were performed in 1936 and were deposited with the Polish Air Forces authorities. Military secrecy did not permit their publication and the manuscript probably was destroyed in September, 1939 at the Institute of Technical Research for Aeronautics in Warsaw. In 1940, in London, the author reproduced from memory these calculations in much condensed form. They were held for sometime because of censorship and were published in 1944 (ref. 10), eight years after they were performed. The conclusions drawn are as follows:

Rocket Wing-Bomb Launched From An Aeroplane

(1) The influence of rocket propulsion in increasing the range of a wing-bomb, as compared with a similar bomb without propulsion, is greater at low altitudes than at higher ones.

(2) From a general point of view, height has more influence than rocket propulsion on the range of a wing-bomb.

(3) Following from (2), the influence of optimum lift/drag ratio and aspect ratio on the range of a wing-bomb is very considerable.

(4) The type of propulsive material of rockets has greater influence at low altitudes, where it is better to use stronger materials. At greater heights, the type of material is less important.

(5) The use of rocket propulsion for wing-bombs may be very advantageous in releasing bombs at low alti-

tudes, for it gives great accuracy of aim. In this case, stronger materials should be used.

Winged Rocket Torpedo Launched From The Ground.

(1) The influence of type of working material is very important. Strong materials should be used.

(2) The distance traversed by the rocket torpedo on the glide is much greater than that of the upward flight.

(3) Following from (2), very high lift/drag ratios and aspect ratios should be used.

(4) The ranges of rocket torpedoes, as given by approximate calculations are considerable and may reach the distance of about 230 miles.

Experiments

The experiments were begun early in the spring of 1935 and were performed by the author with Captain H. Stankiewicz on the military airfield at Lwow (South Poland). The propulsive material used was black powder. The rockets were produced in small quantities by a military pyrotechnist-specialist. The first part of the tests dealt with the value of the force which can be obtained from a powder rocket. The rockets were mounted on a horizontal table and the force was measured by the aid of a spring-scale. The rockets were ignited by a fuse. Those tests showed that from well manufactured black powder rockets, a pressure of 0.5 kg/cm^2 or 7.0912 lbs. per sq. in. may be obtained (ref. 3).

The second part of the tests dealt with flight experiments. The low wing models were made from laminated wood. The wings and fuselage were made separately and later glued together. The wingspan was about $2\frac{1}{2}$ to 3 ft. The airfoil sections used were Gottingen profiles. The wing had a rectangular planform, the fuselage a

square cross-section. Along the axis, the fuselage possessed a long circular hole inside, into which a powder rocket of circular shape was put. At the rear part of the fuselage, tail control surfaces were located of symmetrical airfoil. A series of these models were made. The factors which were subject to change were as follows:

(1) The location of the wing with respect to the center of gravity of the whole model.

(2) The angle of set of the wing with respect to the longitudinal axis of the fuselage.

(3) The angle of set of horizontal tail surface with respect to the longitudinal axis of the fuselage.

(4) The change of center of gravity of the whole model by the addition inside of small pieces of lead.

(5) The angle of inclination of launching device.

The rockets were ignited by a fuse and models were launched at first from the ground from an inclined wooden launching device specially designed with variable angle of inclination. Later, models were launched from the roof of a building. The difficulties met during the tests and results were as follows:

(1) Because of lack of flight control devices and the change of center of gravity in flight, the first models after a short distance of flight assumed a steep glide path towards the ground long before the rocket was burned out.

(2) Many tests were performed in which the wings were transferred towards the front and towards the rear of the fuselage, sections of the wing were changed, the position of center of gravity was changed by the addition of pieces of lead in various places of the fuselage, and the angle of set of the horizontal tail surface was changed.

(3) It was very difficult to find a

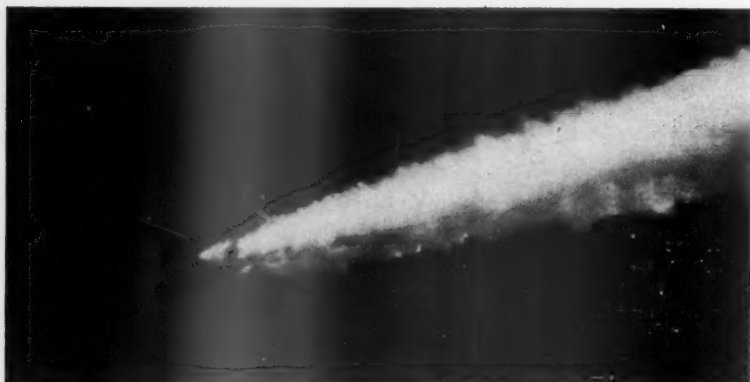
position of center of gravity, location of wing, angle of set of tail surface such as to give a steady horizontal flight path of such a heavy model.

(4) The longest distances of flight were obtained using such a position of c.g., and such a location of wing that the flight path was a slightly inclined climb, with a glide or steep dive after the whole rocket was burned out.

The longest distance of flight obtained during those tests was over 200 yds. Projects were started for the designing of a larger model with control devices, but the tests were stopped

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—U. S. Navy

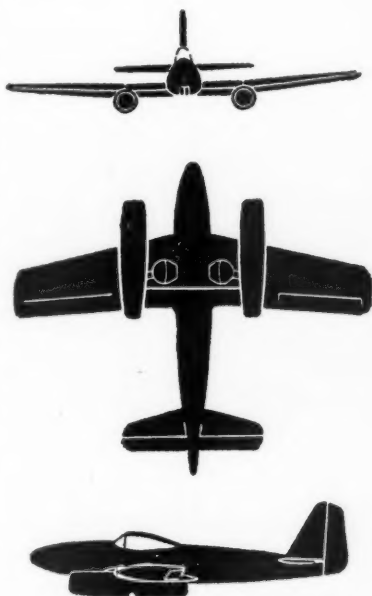
Jet Assisted Takeoff—A massive bi-motored Martin Mariner (PBM) in a jet-assisted takeoff from the water.

Notes On Turbo-Jet Aircraft

Other than Italy's Caproni-Campini jet-propelled plane of the much publicized Milan-Rome flight, England, United States and Germany have each developed a number of designs employing the turbo-jet type of engine. The British line of evolution apparently runs from the Gloster to the Meteor to the new Vampire. Produced by De Havilland, this new fighter plane is powered by a simplified jet engine and has a speed in excess of 500 m.p.h. Developed just before the European war ended, the plane is scheduled for service in the Pacific in the near future. Stemming from the British Gloster jet units, the U. S. has brought forth the Bell Airacomet and the Lockheed Shooting Star with considerable development on later models.

Numerous designs of jet-driven aircraft have been produced in Germany. The often mentioned Messerschmitt Me 163 is rocket powered and does not have turbo-jet units as used in the Me 262, the Heinkel He 280 and the Arado Ar 234. Reports are current of a small single-seater plane with two cannon propelled by an impulse duct engine, and a long-range bomber, said to be the Messerschmitt Me 264, which uses mixed power units of orthodox reciprocating engines and propulsion jets.

It is also interesting to note that at least four models of jet-propelled helicopters were under development in Germany. The aircraft, which were designed to take off and land on small surface craft or submarines by jet power, employed standard engines and rotors for traveling. The single and double-seater models were built at Wiener Neustadt and at St. Poelten, Austria, and were equipped with 60 to 135 h.p. engines. Fuel consumption for one model was estimated at 35 gallons per hovering hour and 10 gallons when traveling.



Me 262 is powered with two Junkers jet units mounted in the wings.

Fuel Selection

The high fuel consumption, a fact disregarded in wartime but most essential in peacetime use, will be largely offset by light weight power plants and low cost fuel. Jet units may be adapted to operate on low grade oil, kerosene, high octane gasoline, powdered coal or even a compressed wood fuel. High octane gasolines with anti-knock properties are not required; B.T.U. content expressing the quantity of heat determines the efficiency of the fuel. The type and mixture ratio of fuel is important due to high combustion temperature limitations of available alloys. The ideal turbo-jet fuel is probably midway between kerosene and gasoline, with careful refining required as at high altitudes the low temperatures have a tendency to solidify the wax content in kerosene.

The Repulsor Rocket

Description Of A British Experimental Design

By A. E. CRAWFORD

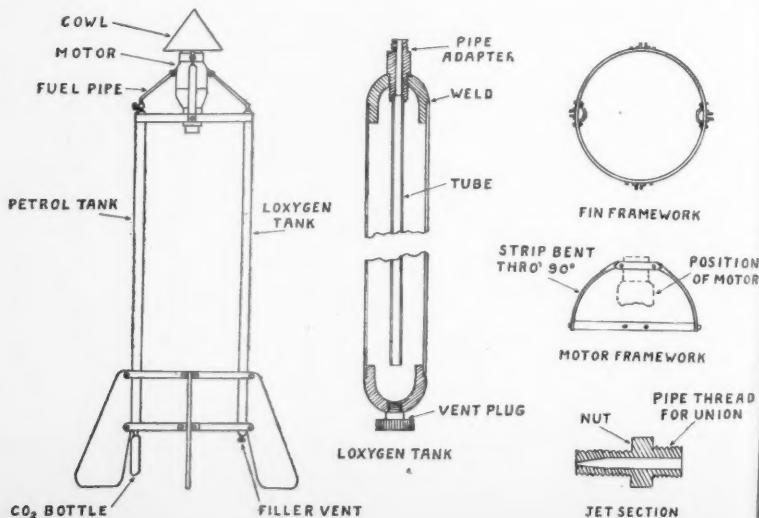
The repulsor rocket, although capable of flight, can be used most conveniently as a test bed for motors. It is of very simple construction and is adaptable for modifications to motors, fuel, etc. As is well known, it was the logical development of the German 'Mirak' rocket and credit must be given to Herr Klaus Riedel for its simplicity of design. It was, of course, the first really satisfactory liquid fuel rocket to be produced and has some fine flight records. It is proposed to describe a modification of this rocket based on practical design and using the minimum of materials and facilities. Although dimensions are quoted in some cases, the description is intended to be of the most general nature as modifications can be made to suit available material and requirements. As described, the rocket was constructed for motor testing and has proved highly satisfactory.

General Description

The general layout consists of two cylindrical fuel and liquid oxygen tanks combined by a framework to form a rigid structure. At the lower end are fitted stabilizing fins. The motor is suspended centrally over the top end and fuel is led to it via pipes from the top of the tanks. A cowl is placed over the top of the motor to provide some attempt at streamlining and to make a space for fitting recording instruments.

Fuel Tanks

The oxygen tank as shown is constructed from a piece of high grade drawn steel tubing 3 ft. long, $1\frac{1}{8}$ in. outside diameter and 14 gauge thick. The tubing should be carefully selected for freedom from cracks, dents, and flaws of any kind; if the specification is deviated from it should be stressed out to give a safety factor of at least



X3 over the operating pressure that it is planned to use in the fuel tanks. Ends are turned as shown and carefully welded into position, preferably using oxy-acetylene equipment. The lower end has a $\frac{3}{8}$ inch B.S.F. tapped hole provided in it for filling purposes; this is normally closed with a shouldered bolt. A fibre washer is provided to make the joint gas and liquid tight. Fibre has been found to stand up best under the temperature condition imposed on it. The top cap has a hole into which a piece of copper of similar tubing is brazed. This tube is just long enough to reach the bottom of the casing, and is to ensure that liquid oxygen reaches the combustion chamber by being forced under the pressure of gaseous oxygen at the top of the tank. Into the outer side of the end cap is screwed a double ended bush provided with a gas thread to take a standard union nut. The diameter of hole through the copper tube and bush should be sufficient to take the maximum rate of flow that the motor is designed for.

The petrol tank, about 10 inches distance from the oxygen tank is of similar construction with the exception of two items. The filler bolt is replaced with a fitment to take a 'Sparklet' soda siphon recharger or similar small tube of compressed gas, for forcing the petrol into the combustion chamber. The compressed gas most generally used is carbon dioxide but it may be possible to use a combustible gas, thereby providing a little extra fuel. Instead of the double ended bush, a small tap such as a standard gas cock is used. This provides a control of the fuel flow for combustion mixture adjustment and ease of handling.

Framework Construction

The supporting framework is made entirely from 1 inch by 16 gauge mild steel strip. Three hoops 11 inches in diameter are made up by lapping the ends over an inch or so and riveting

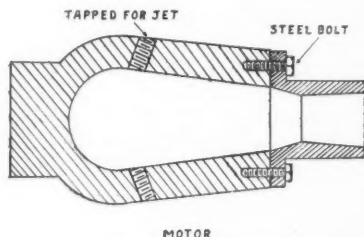
or welding in position. Pipe clips are made up to suit the diameter of the fuel tanks and are positioned and clamped by two B.A. cheese head screws and nuts. The two lower hoops are provided with four lugs each, welded or riveted on. The lugs have a clearance hole through them to fix the fins in position. The top hoop has a diametrically placed semicircle of strip secured to it; the strip is twisted through 90 degrees at its midpoint and shaped to fit round the top of the motor. A loose clip is provided for clamping the motor in position.

For the sake of compactness when packing for transportation, nuts and bolts were used on the original model, but in most cases rivets and welding could replace them.

The fins are made from 18 gauge sheet duralumin and are cut to a suitable shape. A size suitable for the suggested framework would be 12 inches by 6 inches.

Motor And Jets

The motor and fuel jets will be described briefly but it is, of course the major part of the rocket, and can be made to any form desired by the constructor—concentric feed, fuel whirls, thrust augmentors, etc. can be constructed to suit personal needs.



The simple motor made for initial experiments was constructed from 3 inch diameter duralumin, the chamber was bored out on a lathe to proportions decided by the size of jets and desired thrust, the nozzle piece being similarly

bored and smoothed to a venturi outline. A parallel shank is turned at the tuyere end to enable a thrust augmentor to be fitted if desired. Holes are drilled for four $\frac{1}{4}$ inch B.S.F. bolts, and counterbored to provide a seating for the boltheads.

A simple set of jets can be made as pictured. They are machined from steel and are screwed to fit into the motor; a pipe thread is cut at the inlet end to suit a pipe union. The body is provided with a hexagon shaped collar to enable a spanner to be used for tightening purposes. The dimensions of the jets are of course decided by the theoretical design of the rocket while the bores should be polished to a mirror finish to reduce friction to a minimum.

A cowling is provided to increase motor cooling and to provide a space for a small recording accelerometer or other instruments. It is bent up from 24 gauge sheet duralumin and is held in position by small wing nuts and bolts. If desired, the whole cowling including the instruments can be released after the rocket reaches its maximum height and a small parachute arranged to return the record safely.

It is hoped that this brief description is sufficient to encourage enthusiasts to construct their own rockets. No attempt has been made to discuss the theoretical design of rocket motors but a great deal of data has been published in the past by the Manchester Astronautical Association, the Astronautical Development Society, and the British Interplanetary Society.

The C.B.A.S.

Correspondence with the Combined British Astronautical Societies reveals that the British groups are holding a number of special meetings for the purpose of discussing the future policy of the organization. The main issues to

JAPANESE SUICIDE ROCKET BOMBS

Airplane-launched glider-type rocket bombs have been used by the Japanese Kamikaze, or special suicide corps, since April 12 in attacks on Pacific Fleet surface units in the battle for Okinawa. The human-piloted, twin-tailed Japanese version of the German glider bomb has been named by the Americans "Baka" bomb, a derisive Japanese term meaning stupid or foolish.

Constructed of wood and light metal, the one place jet-propelled bomb has a wingspan of 16 ft., is almost 20 ft. long and has an 8 ft. tailplane. Launched from the underside of a Betty or other large bomber generally at a 3 mile altitude, the projectile may attain speeds of 500 m.p.h. the first minute of flight from the impulse of the tail rocket motor.

The pilot rides astride the projectile under a streamline transparent canopy and exercises moderate control by side-slipping and other maneuvers to guide the bomb to the target. Due to the high speeds involved, the Baka bombs are difficult to steer allowing a surface craft to dodge by evasive action, though a number of hits has been scored. As no landing gear is attached, the pilot is doomed if the bomb hits its objective thereupon exploding the half-ton warhead of explosives or misses it completely. When released from a 6 mile altitude, the rocket bomb due to its initial jet power and gliding possibilities is reported to reach ranges of over 100 miles.

be debated concern the single society idea, future name, types of membership, publications, formation of committees and line of development in the postwar era.

Mr. A. E. Crawford, who has an article in this issue, was recently elected to Fellowship from membership.

Fifteen Years Of Organized Rocketry

The American Rocket Society Notes Its Anniversary

On the evening of March 21, 1930, a dozen men gathered in an apartment at 450 West 42nd Street, in New York City, to form an ambitious society for the "promotion of interest in, and experimentation toward interplanetary expeditions and travel . . . the stimulation by expenditure of funds and otherwise of American scientists toward a solution of the problems which at present bar the way toward travel among the planets, and the raising of funds for research and experimentation."

It was the first meeting of a group which then called itself "The American Interplanetary Society" and which subsequently became the American Rocket Society. The year 1945, consequently, marks the fifteenth anniversary of the Society, and of organized rocketry in this country; a decade and a half which has seen the rise of rocketry and jet propulsion from an obscure and somewhat fantastic hobby to the status of a major engineering field and wartime industry, employing hundreds of thousands of people and producing jet propulsion engines, thrusters, jets, jet planes and rockets valued at more than \$1,000,000 annually.

The leader of the original organizing group was David Lasser, a graduate of the Massachusetts Institute of Technology, and then editor of a popular science-fiction magazine called *Wonder Stories*. Mr. Lasser, now a government official in Washington, D. C., became the first president of the Society.

Other founders included C. P. Mason, a writer and editor, who was the first secretary; Fletcher Pratt, the noted writer and authority on naval and military matters; Clyde J. Fitch, an engineer now connected with the International Business Machines Company; C. W. Van Devander, a newspaperman;

Laurence Manning, a writer and businessman, who is at present a member of the Society's Board of Directors; Nathan Schachner, a lawyer and noted writer; and Dr. William Lemkin, chemist, teacher and writer of textbooks in technical fields.

Mr. Van Devander, who is now a newspaperman in Washington, D. C., became the editor of the Society's first publication, known as the *BULLETIN*. G. Edward Pendray, in whose apartment the organization meeting was held, was elected vice-president, and given the assignment of organizing a research program.

First Activities

The Society's first public activity was to arrange a ceremony in which Captain Sir Hubert Wilkins, the explorer, presented to its library an old copy of one of the earliest books on interplanetary travel, *The Discovery of a New World*, by John Wilkins, Bishop of Chester, written in 1640. Bishop Wilkins was a distant ancestor of Sir Hubert's. In the same ceremony, the explorer became a member of the Society.

The second public activity of the organization was to provide for an address at the American Museum of Natural History in New York by Robert Esnault-Pelterie, the famous, French engineer, airplane builder and rocket enthusiast. The auditorium at the Museum holds 1,500 persons, but so great was the crowd attracted to this address, that enough people came to fill the seats twice over. An overflow crowd of more than 1,000 persons remained outside throughout the first performance, and nearly filled the auditorium again at ten o'clock, when the entire program was repeated.

The Society was thus well launched. The membership climbed. Among the

well-known American scientists and engineers who joined were Dr. H. H. Sheldon, professor of physics at New York University; Dr. Alexander Klemm, head of the Guggenheim School for Aeronautics at New York University; Dr. George V. Slottman of the Air Reduction Company; Mr. John O. Chesley of the Aluminum Company of America; Dr. James H. Kimball, of the United States Weather Bureau, and Dr. Robert H. Goddard, the founder of modern rocket research and the foremost figure in our time in rocketry and jet propulsion.

Early Research

The experimental program of the Society got under way, in general, in 1931. Early in that year, Mr. and Mrs. Pendray had an opportunity to go abroad. They planned their trip in such a way as to enable them to study what the European experimenters were doing. The Society named them its official representatives, and they had excellent opportunity to learn what was going on in rocketry in Italy, France and Germany.

They found to their dismay, that most of the European "rocket experiments" which had so much excited the American public at the time were mostly publicity stunts, of little or no scientific value. At Berlin, however, they met Willy Ley, with whom Mr. Pendray had previously had much correspondence. Ley introduced them to the interesting and suggestive experiments then being carried on, with what are now called "solid" liquid fuel motors, by the Verein für Raumschiffahrt (German Rocket Society) near Berlin.

Mr. Pendray's report on the German experiments was given before the Society on the evening of May 1, 1931, and appeared in a somewhat condensed version in the May issue of the BULLETIN. It marked the beginning of liquid fuel experiments in this country, other than the work of Dr. Goddard,

who had, of course, been using liquid fuels in his motors since about 1920.

Shortly after the May 1931 meeting, H. F. Pierce, who later became president of the Society, proposed that experimental work begin at once. An experimental committee was formed. Mr. Pierce and Mr. Pendray designed, more or less by rule of thumb and what guidance they had from the German data, the Society's first liquid fuel motor and rocket.

Publications

The rest of the story of the American Rocket Society to date is told in the early issues of the BULLETIN, and subsequently in ASTRONAUTICS, now the JOURNAL. Before the war, the Society was the largest and most active organization of rocket experimenters in the world. It had an elaborate experimental program of its own, and in addition, many of its more than 300 members were also carrying on research in rocketry and the various phases of jet propulsion.

It had by that time produced, in the issues of the BULLETIN and ASTRONAUTICS, one of the largest accumulations of data, information, theory and conjecture about rockets and jet propulsion available in any language, and by far the largest in English.

Experiments

It had performed literally hundreds of tests of motor designs, fuel combinations, rocket designs, aerodynamic experiments, studies of dry fuel and liquid fuel problems, parachutes, catapults and the like. The data obtained from these tests were all duly reported in the Society's publications for the use and guidance of other engineers and experimenters.

It had, through a long series of tests covering a period of more than five years, encouraged and made possible one of the first practical regenerative

liquid fuel motors—the so-called Wyld regenerative motor — named for its originator, James H. Wyld, who later became president of the Society. The Wyld regenerative motor was the progenitor of liquid fuel motors which played a major part in the liquid fuel jet propulsion apparatus developed for military use during the war.

It had made and shot many rockets, including a notable series of liquid fuel rockets culminating in the shot of rocket No. 4, designed by John Shesta, later chairman of the Society's Experimental Committee and now a member of the Board of Directors. Mr. Shesta's rocket was shot on September 9, 1934, at Marine Park, Staten Island, New York. Its observed velocity at one point exceeded 1,000 feet per second—about 700 miles an hour.

Prewar Accomplishments

It had done much to establish the whole field of rocketry and jet propulsion—which up to then had been too much the realm of fantasy writers, publicity stunts and unsound theorists—on a reliable and wholesome engineering basis, with technical reports of its work, an analysis of the engineering problems to be solved, and an orderly approach to their solution. With its publications and experimental work, as well as the educational work it carried on with the public, it laid the groundwork for a great deal of the thinking and development in jet propulsion that came with such suddenness during the war.

Finally, perhaps the most important of the Society's prewar accomplishments was the subtle one of training a number of young engineers and technical men in the thinking and "know-how" of rocketry. Many of these men—Alfred Africano, John Shesta, Roy Healy, H. F. Pierce, Lovell Lawrence and James Wyld, to name just a few—are now in key positions in the war

effort. Though the nature of their work is necessarily undisclosable at present, it is proper to note that they have all made extremely important contributions to rocketry and jet propulsion in the war.

Present Aims

The Society is now changing from an essentially amateur group of experimenters (there were no professional rocket and jet propulsion engineers before the war) to a professional engineering society, devoted to the furtherance of rocket and jet propulsion engineering, and the general advancement of this new and growing field. The membership has enlarged rapidly during the war; likewise the demand for the Society's publications. It is hoped that regular monthly meetings can be resumed by next autumn—meetings which were discontinued at the request of the military authorities for security reasons soon after Pearl Harbor.

The Society has affiliate groups, some of which have commenced to consider postwar research programs of their own. Other affiliates are being encouraged on a regional basis, offering the Society a means of becoming truly national in character.

So ends the American Rocket Society's first fifteen years. It looks forward to the coming fifteen years with expectation and enthusiasm.

—G. E. P.

ERRATUM

In the article, "Frictionless Flow In A Rocket Motor, the factor

$$\frac{2}{n+1}$$

appearing under the radicals in Equations (2) and (5), as well as in that giving values for A_m , should read

$$\frac{2}{n-1}$$

The New York Rocket Battalion

Experiences Of A Civil War Rocket Unit

Shortly after the start of the War of Secession a public meeting was held at the town of Perry, Wyoming County, New York State, to interest the citizens in forming a light artillery company. Some twenty volunteers to the cause journeyed to Fort Porter, Buffalo where they joined a similar group from Monroe County. Proceeding to Albany the men on December 6, 1861 were mustered into the service of the United States to serve three years.

Major Thomas W. Lion, a British officer who claimed improvements on the Congreve war rocket, organized the Wyoming-Monroe group together with several other squads into a rocket battalion. The 160 men in the battalion were divided into two companies, A and B, led by Captain Alfred Ransom and Captain Jay E. Lee, respectively. The battalion went by steamer to Washington, D. C. to receive the necessary training and equipment. At the capital the enthusiastic unit changed the name of their encampment to Camp Congreve, in honor of the rocket inventor, but were obliged to wait four long months before receiving the much vaunted "rocket guns."

Rocket Artillery

The standard rocket of the time had an overall length of 12 to 20 inches with a diameter of 2 to 3 inches. Surmounted by a conical solid iron head, the hollow rocket body contained the fuse-ignited propellant powder. These rockets were accredited with a range of three miles. The sheet-iron launchers either consisted of a 3 inch hollow tube or three $\frac{3}{4}$ inch rocket-guiding rods bound in an open framework by sturdy bands. Advantages claimed for the rocket were: limitless size, negligible recoil, speed of firing, easiness of transportation, lightness and simplicity of launching equipment, and resultant

confusion created among mounted troops.

An improved design of rockets were to be used by the battalion. The hollow warhead was designed to carry seventy-four musket balls with powder to be exploded in grapnel fashion at a predetermined point by a time fuse. Ignited by a fuse the inflammable compound in the rocket body created large gas masses which on expelling through tangentially placed outlets gave a forward spiral motion to the rocket. The imparted spin and heavier head were considered to aid the stability of the rocket giving a straighter flight and greater range.

The wrought iron rocket projectors were 8 feet long with $2\frac{1}{4}$ inch bores. Inch in diameter holes for the rocket's exhaust gases perforated the tubes throughout. Four rocket-launching tubes were mounted on each of the four lighter than usual carriages enabling the gunners to discharge 16 rockets at one volley.

In April 1862 the battalion tested the rockets by discharging them at an army blanket hung as a target a mile away. A number of faults appeared, the most common the failure of the projectile to hold a true course reverting in some cases in a retrograde movement. Due to the urgent need for light artillery replacements the rocket equipment was exchanged for rifled cannon, and shortly afterwards the battalion left Washington. On February 11 of the next year the rocket battalion was officially changed to the Twenty-third and Twenty-fourth Independent Batteries New York Artillery.

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A Vocabulary For Jet Propulsion

Part II — An Astronautical Nomenclature

By G. EDWARD PENDRAY

This part completes the list of words and phrases used in the field of jet propulsion. The first section of the glossary was published in JOURNAL No. 61.

Chamber pressure—Pressure shown by a gage connected to the combustion chamber during firing.

Chemical fuel motor—A true rocket motor, using propellants supplying their own oxygen (as opposed to the air-stream engines, which obtain their oxygen from the air).

Chugging—Irregular combustion due to incorrect mixture or poor chamber design.

Chute boot—The parachute container of a sounding rocket.

Combustion chamber—An alternative term for blast chamber.

Compressibility burble—An unsteady type of airflow around an airfoil operating close to the speed of sound, marked by reduced useful lift and increased drag, caused by shock waves on the airfoil surface.

Concentric tanks—Fuel or propellant tanks nested one within the other, with a common central axis.

Construction weight—The weight of tanks, motor, pumps, controls, landing gear, etc. of a rocket, exclusive of fuel. (Same as **structural weight**).

Controlled rocket—A rocket which has a guiding mechanism capable of controlling the direction of flight.

Coolant—Any material used to cool a rocket combustion chamber or nozzle.

D

Delayer—A substance mixed with the propellant of a dry-fuel rocket to slow down the rate of combustion.

Dipropellant—A combination of two substances used as a rocket fuel.

Dissociation—Decomposition of the burned gases in a combustion chamber at high temperature, producing a loss of heat energy.

Drag coefficient—A factor representing the relative air resistance of a particular shape of airfoil or hull, used in air-drag calculations.

Drop unit—A booster rocket which can be jettisoned after exhaustion of its propellants.

Dynamometer—A device for indicating and recording the thrust of a rocket motor during test, also called a **reaction balance**.

E

External efficiency—The ratio between the energy usefully employed in propulsion and the kinetic energy developed by the jet. (Same as **ballistic or mechanical efficiency**).

Escape velocity—The velocity at which an object would escape the gravitational attraction of a given astronomical body. The escape velocity of the earth is 6.664 miles per second.

F

Fill-hole—The orifice through which liquid fuels are loaded into a rocket's tanks.

Final mass—The mass of a rocket at the end of powered flight.

Fins—Fixed rudders on a rocket to help give it direction.

Fizz pot—An airplane booster rocket.

Flaps—Movable rudders, either attached to the fins or placed in the jet of a rocket, to direct the flight.

Flare—The bell-shaped inner curve of some types of rocket motor nozzles.

Free flight—The portion of a rocket's flight which follows the combustion of the fuel or the turning off of the rocket motor.

Free rocket—A rocket which has no guiding or flight control devices other than fixed tail or fin surfaces.

Ft/sec (or fps)—Feet per second, frequently used in connection with measurement of jet velocity.

Fuel—The combustible component of a rocket propellant; through this term is often used also to denote the oxidizer as well.

Fuel-weight ratio—The ratio of the weight of a rocket's fuel to that of the empty rocket without fuel. Also called the **fuel structure ratio**. It is equal to the **mass ratio** minus 1.

Fusee—A small pyrotechnic squib used for igniting a rocket motor.

G

g—Symbol for **gravity**, the unit of acceleration, equal to 32.2 feet per second per second.

Gyrocontrol—A gyroscopically operated device for guiding a rocket in flight.

H

Hull—The outer casing of a large rocket projectile

I

Ideal rocket—A rocket constructed to such a weight-fuel ratio that it will reach the velocity of its own jet. In a gravityless vacuum this ratio would be 1 to 1.72; the larger number referring to the fuel; in air the ratio is 1 to 2 or better.

Impulse—The total output of a jet motor in a given shot; equivalent to average reaction multiplied by time.

Impulse-weight ratio—The ratio between impulse (reaction multiplied by

total firing time) of a jet motor and the total loaded weight, including auxiliaries.

Igniter—A device for igniting a rocket motor.

Initial mass—The mass of a rocket at the beginning of flight.

Initial velocity—Velocity of a rocket at the start of the firing period.

Injector—The inlet device which admits propellants to a rocket motor.

Inlet ports—The openings or nozzles through which propellants are injected into the rocket motor.

J

Jato—Apparatus for producing jet assisted takeoff, or an airplane so equipped.

Jet—The stream of gas ejected by a rocket motor.

Jet-assisted takeoff—An airplane take-off accelerated by the use of a thruster rocket or jato.

Jet engine—An airstream engine; a reaction motor equipped to use oxygen of the air as an oxidizer.

Jet propulsion—Rocket power: propulsion by thrust developed by ejecting a jet of rapidly moving gas or other substance through a nozzle.

L

Landing gear—Equipment, usually consisting of a parachute and release mechanism, for bringing a rocket gradually to earth after a shot.

Launcher—The aiming device from which a rocket is shot.

Launching angle—The angle, measured from a horizontal plane, at which a rocket is inclined at launching.

Launching rails—A rocket launching device, usually attached to an airplane.

L/d³ ratio—The ratio of length to diameter of a rocket motor combustion chamber.

Liquid-fuel rocket—A rocket driven by a motor burning liquid propellants.

Loaded weight—Weight of a rocket or jet motor apparatus loaded with propellant and ready to fire.

Lox, or loxygen—Liquid oxygen.

M

Mach number—The ratio of the velocity of a rocket or a jet to that of sound in the medium being considered.

Mach waves—Nodes or standing waves in a rocket motor jet, caused by reflection of the jet from the surrounding air.

Mass ratio—The ratio between the total initial mass of the rocket ready to shoot and the final mass of the empty rocket. Also called **weight ratio**.

Mechanical efficiency—The ratio between the energy usefully employed in propulsion and the kinetic energy developed by the jet. (Same as **ballistic or external efficiency**).

Metering orifice—A constriction in a liquid feed line for regulating the propellant flow rate.

Monopropellant—A propellant consisting of a single liquid, which contains both fuel and oxidizer, either combined chemically or in a mixture.

Motor head—The forward portion of a liquid-fuel rocket motor, usually containing the propellant injection ports and the igniter.

Mouth—The large end of the expansion nozzle of a rocket motor.

Mouth area—The cross-section area of the nozzle mouth.

Multinozzle motor—A rocket motor with more than one nozzle.

N

Nozzle—The orifice and expansion device through which the jet is ejected from a rocket motor.

Nozzle coefficient—The amount, experimentally determined, by which the shape of a specific nozzle increases the thrust of a motor.

O

Oxidizer—The oxidizing component of a rocket propellant, in general a substance containing or consisting of oxygen available for combustion.

P

PSF ratio—The payload-structure-fuel weight ratio.

Parachute release—An automatic device for ejecting a landing parachute from a rocket.

Payload—The useful load carried by the rocket, in addition to its necessary structural weight and fuel.

Payload-structure-fuel weight ratio—The ratio between the payload, the structural weight and the fuel weight; sometimes called the PSF ratio.

Powered flight—The portion of a rocket's flight during which the rocket motor is in operation.

Pressure gas—A gas, usually nitrogen, used to force the propellants of a liquid fuel rocket into the blast chamber during firing.

Pressure ratio—The ratio between chamber pressure and the pressure at the nozzle mouth (or other reference point).

Propellant—The materials used in a rocket motor to produce the driving jet.

Projected area—The maximum cross section of a rocket hull, when viewed head-on.

Proving stand—An equipment for testing or "proving" rocket motors. Also **test stand**.

Pyrotechnic fuel—A solid propellant which supplies its own oxidizer as part of the mixture, as in the case of gunpowder.

R

Reaction—The recoil or "kick" produced by the jet of a jet motor, which provides the propulsive force.

Reaction motor—The general term for all types of motors and engines that operate by jet propulsion.

Regenerative motor—A liquid fuel rocket motor equipped with a cooling jacket, through which the fuel flows on its way to the injector, thus carrying the waste heat back into the blast chamber.

Resojet—An intermittent duct engine, sometimes called the **buzz-bomb engine**.

Rocketor—A rocket engineer or rocket experimenter.

Rocketry—The field of rocket research, engineering and experimentation.

S

Sectional density—The weight of a rocket divided by its maximum cross section. Used in estimating air-resistance.

Self-contained motor—Same as **chemical-fuel motor** or **true rocket motor**.

Servomotor—A mechanism to make force act at a distance, proportional to the force impressed upon it, as in gyrocontrol mechanisms which guide rudders on steered rockets. In particular, pneumatic or hydraulic cylinders used for this purpose.

Shock waves—Sound waves set up by an object moving at supersonic speeds, causing increased energy losses.

Shot—A rocket flight.

Spinner—A winged device like the rotor of an autogyro, used instead of a parachute to bring a rocket gently to earth.

Solid-fuel rocket—A rocket propelled by a solid pyrotechnic propellant; a **dry-fuel rocket**.

Sounding rocket—A high-altitude rocket carrying air-sounding equipment.

Step rocket—A rocket consisting of several sections or "steps" fired successively, each step being jettisoned when its fuel is exhausted.

Subsonic velocity—A velocity less than that of sound.

Supersonic velocity—A velocity greater than that of sound.

T

Tandem-tank rocket—A rocket with cylindrical propellant and pressure tanks placed end to end; a **single-stick rocket**.

Taper—The angle at which some types of rocket nozzles open out from the throat.

Thermal jet engine—A type of air-stream engine containing a rotary air compressor to provide air under pressure to sustain combustion.

Thermal efficiency—The ratio of the kinetic energy developed by the rocket jet to the thermal energy content of the fuel.

Third Law of Motion—Sir Isaac Newton's statement of the principle upon which the reaction motor works: "To every action there is always an equal and contrary reaction; the mutual actions of any two bodies are always equal and oppositely directed."

Throat—The narrowest part of a rocket motor nozzle.

Throat area—Cross-sectional area of the smallest part of the nozzle.

Thrust—The push produced by a jet or rocket motor.

Thrust augmentor—A funnel-like device for guiding the surrounding air into a rocket motor jet, thus producing suction which increases the thrust.

Tracker—A mechanism for observing

ROCKETRY NEWS

V-3 Long Range Rockets

During the months of February and March experimental German V-3 long-range rockets were launched against England. The V-3 was described as a 120 lb. two-stage projectile, jet driven and carrying 40 lbs. of explosive in the warhead. Upon depletion of the fuel the propelling section fell off and the warhead continued on alone.

A battery of some fifty launching barrels at Marquise Mimoyecques, near Calais, which was first neutralized by bombing then captured by the Allied armies, was found to be provided with underground barracks, storerooms, etc., some 300 feet deep. Six-inch caliber projectiles were to be launched from the 400 foot smoothbore barrels, which lack

or controlling a flying rocket from the ground, or the man operating such a device.

Trajectory—The curve which a body, as a missile, describes in moving through space under the influence of the force of gravity.

True rocket motor—A self-contained or chemical fuel motor.

Turbo-jet—A thermal jet engine in which the compressor is driven by a gas turbine.

V

Valve man—The operator who actually fires a liquid fuel rocket.

Vj—The jet velocity of a rocket motor.

W

Warhead—The explosive section of a military rocket.

Weight-fuel ratio—The ratio between the structural weight and the fuel weight.

Weight ratio—Same as mass ratio.

Wetted surface—The total external surface of a streamline hull exposed to air friction.

of rifling made adequate for firing numberless rounds. When perfected, ten rockets per minute were to rain night and day on London, supplemented by V-1 robot bombs and V-2 long-range rockets.

Featherweight Bazooka

General Electric Company recently announced that the seventh basic bazooka design is 42 percent lighter but carries the usual heavyweight punch. Made of aluminum, the 10½ lb. weapon has greater wall thickness than used on the standard steel models. A new type of eyesight improves the accuracy over previous models. Representing several years of research the design is now in production.

British Rocket Projector

A new type rocket projector used for medium artillery barrage work by British troops is described as "one of the war's most devastating weapons." Each rocket projector has thirty-two barrels which discharge missiles of a smaller size but comparable with a 100 lb. shell of the orthodox 5.5 inch gun. The twelve projectors of each barrage group deliver 384 rockets comparable in firepower to 280 5.5 inch guns.



—North American
A B-25 showing four machine guns
and three rocket tubes.

BRITISH PATENT SPECIFICATIONS

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(Continued on Page 20)

BOOK REVIEWS

The Coming Age of Rocket Power. by G. Edward Pendray. Harpers and Brothers, New York, 1945; 244 pages, \$3.50.

The story of the rocket from its discovery in China centuries ago to modern wartime developments in the robot, the bazooka and the jet-propelled plane is comprehensively told by the present Secretary of the Society. The reaction principle, rocket fuels, types of rocket motors and airstream engines, design and construction details are fully explained. Descriptions are given of jet devices in peace and war, and the rocket weapons as employed today.

There is an informative treatment of rocket societies and methods of research and experimentation. Future potentialities of postwar transportation by rocket and the possibilities of interplanetary flight are presented by the author. Numerous drawings and photographs supplement the text, and also is included an appendix with a useful glossary of rocket terms and an index.

Spacewards, Official Organ of the Combined British Astronautical Societies. Vol. 6, No. 2, January 1945; 14 pages, 1s.

Concentrating on society news, the editorial comments focus attention on meetings of the society, while the major part of the periodical contains reports of a general meeting of the Northern Branch and a technical meeting of the Southern Branch. An article on the ideal astronautical society is presented, and a brief mention of a radio type of altimeter first reported in *ASTRONAUTICS*. A photograph of Gerhard Zucker's 1931 aerial torpedo is shown on the front cover.

The Modern Gas Turbine. by R. Tom Sawyer. Prentice-Hall, Inc., New York, 1945; 216 pages, \$4.00.

This work covers the latest information on the application of the gas turbine as a supercharger and prime mover in all fields of service, including jet propulsion. Fundamentals, early inventions and history of the gas turbine, and its many uses with modern engines are discussed. A chapter considers applications of the exhaust turbosupercharger to aircraft engines.

The last chapter of the book includes material supplied by G. Geoffrey Smith, author of "Gas Turbines and Jet Propulsion for Aircraft," with the addition of theoretical calculations and performance characteristics on the operation of the jet-propelled plane and jet propulsion. The edition is profusely illustrated with photographs, drawings, graphs and tables.

Gas Turbines and Jet Propulsion for Aircraft. by G. Geoffrey Smith. Aero-sphere, Inc., New York, 1944; 124 pages, \$3.00.

This revised American edition contains additional material on thermal jet propulsion systems with rotary, reciprocating or combined units, and surveys steam and gas turbines driving airscrews. A description is given on the working cycle of a turbine-compressor unit, with new chapters on turbine-compressor units, jet versus airscrew, boundary layer control and broadcast talks on turbine-compressors. Also included is a new introduction, foreword, and biographic sketches of Group Capt. Frank Whittle and others who developed the jet planes. The volume dedicated to the Institute of the Aeronautical Sciences, is well illustrated and indexed.

Book Notes

A reprint of the article "The Day Dawns for Jet Propulsion" from the March 1945 issue of Westinghouse Engineer has been arranged in pamphlet form for distribution to members of the Society. Much useful information, in this discussion prepared by Westinghouse engineers, was obtained from G. Edward Pendray's "The Coming Age of Rocket Power."

The book "Aircraft Armament," by the noted armament expert, Louis Bruchiss, published by Aerosphere, contains all available material on offensive and defensive aircraft armament of the world. Chapters on rocket weapons and future war armament are also presented.

(Continued from Page 18)

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—C. G.

THE ROCKETOR'S LIBRARY

The Coming Age of Rocket Power, by G. Edward Pendray.	\$3.50
Gas Turbines and Jet Propulsion for Aircraft, by G. Geoffrey Smith.	\$3.00
Rockets, The Future of Travel Beyond the Stratosphere, by Willy Ley.	\$3.50
Shells and Shooting, by Willy Ley.	\$2.00
Rocket Research, by Constantin Paul Lent.	\$5.00
Rockets and Jets, by Herbert S. Zim.	\$3.00
Rockets, Dynamators, Jet Motors, by A. L. Murphy.	\$2.50
The Modern Gas Turbine, by R. Tom Sawyer.	\$4.00
Astronautics, Nos. 1 to 60, each.	\$1.00
Journal of the American Rocket Society, each.	\$1.00
Bibliography of Rockets and Jet Propulsion.	\$0.50
Miscellaneous Drawings (Set of 12).	\$1.00
Index to Astronautics.	Free

Rocket Projectile Explosive

Pentolite, a superexplosive having 20 percent more power than TNT, is being used for bazooka ammunition and other rocket projectiles. In one production method, 5-40 percent of PETN (pentaerythritol tetranitrate) is mixed with TNT forming a mixture nearly as powerful as PETN and which retains TNT insensitivity to shock. The Pentolite is heated to a pasty form and then poured into the projectiles, thereby eliminating the usual press loading method.

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Editor, Cedric Giles.

Jet Fi

Shooting Star

Further Details On The P-80

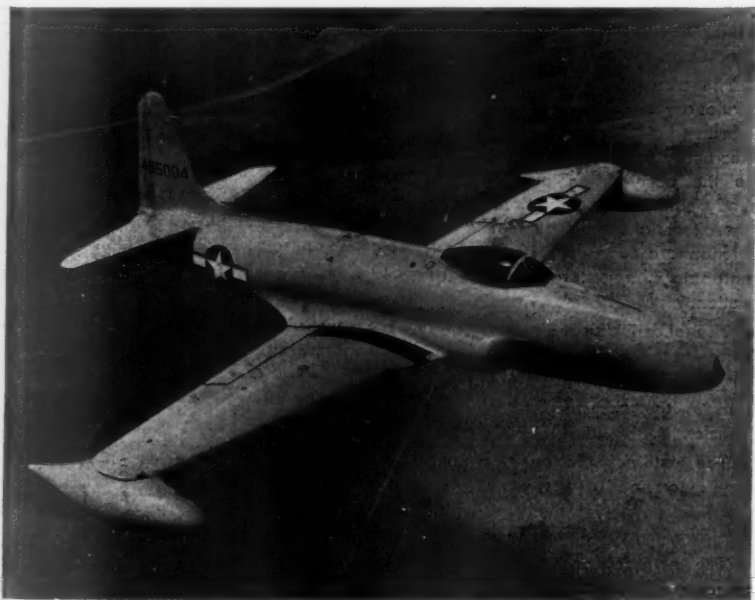
In conjunction with the recent public demonstration of the jet-propelled P-80 Shooting Star additional details were released by the Army Air Forces. The first prototype of the Lockheed Shooting Star was test flown on January 9, 1944. Numerous prototypes powered by a new General Electric high-thrust turbo-jet engine were tested before the design was placed in production.

The wing span of the P-80 is 38 ft. 10½ in., overall length, 34 ft. 6 in., and height, 11 ft. 4 in. Total weight with maximum fuel load is calculated at 14,000 lbs. and total weight empty approximately 8,000 lbs. Capable of speeds in excess of 550 m.p.h. and a ceiling well above 45,000 ft., the plane carries droppable fuel tanks on the extreme tips of the wings for increas-

ing its range.

The GE turbo-superjet I-40 unit, mounted behind the cockpit, has a rotation of over 10,000 r.p.m. Air from the forward twin intakes is forced by the centrifugal flow compressor into fourteen combustion chambers arranged radially. Injected fuel (kerosene) burns and the expanded gases drives the turbine, which is coupled to the compressor, and exhausts through the tail nozzle producing thrust.

Absence of propellers permits the use of a low tricycle landing gear with small wheels. The small armor plated cockpit has good visibility and is pressurized and air-cooled. The throttle is the only engine control needed while the instrument panel is greatly simplified.



—U. S. Army Air Forces

Jet Fighter—AAF Lockheed P-80 Shooting Star in flight with auxiliary fuel tanks.

General Theory Of Reaction Propulsion

Formulae That Applies To Rockets And Jet Motors

By ZYGMUNT FONBERG

The general formulae for reaction derive from Newton's Laws of Motion.

These three fundamental laws define every movement of any body and obviously include the movements of rockets and jet propelled craft. The third law of motion is difficult for some people to apply to jet propulsion motors because they cannot fix the reference point between the acting force and the motion of reaction motors. That is why some believe that for rockets or jet motors to produce force, the force must act on some matter as the air. This is not true because the reaction force is strictly an internal force of the body created by loss of energy by the body. For practical purposes of calculation, the reference point will be considered as a particle of air through which the rocket or jet propulsion motor is moving.

The atmosphere can be considered stationary relative to the earth or starting point, but this concept is only necessary when the inertia force due to the acceleration of the propelled body enters the calculation. However, the effects of inertia, air resistance and friction are secondary items which do not enter the general formula for reaction.

The following definitions will be used in the text below:

The thrust force is the reaction effect due to the gases escaping from the nozzle.

The external efficiency, which will be determined by the ratio of the total energy generated in the nozzle and the energy useful for propulsion.

The external or useful power will determine the power used for the motion of the propelled body.

The external efficiency and external power of the jet motor or rocket is

equal to zero when it is at a standstill, and all the energy generated in the nozzle is wasted, but its thrust is then at a maximum.

The internal efficiency will be the ratio of the total energy of the fuel burned in the motor and the energy generated in the nozzle.

Definitions:

E—kinetic energy generated in the nozzle

E_1 —wasted energy

E_2 —useful energy

u_1 —speed of propelled body

v —speed of gases relative to the nozzle

u_2 —speed of gases relative to the air

P—useful power

m—mass

T—time assumed as 1 sec.

F—reactive force or thrust

Total kinetic energy generated in the nozzle is:

$$F = \frac{mv^2}{2}$$

Wasted energy due to the differences in the speed of the propelled body and speed of gases lost through wasteful agitation of the air through which it is moving:

$$E_1 = \frac{mu_2^2}{2}$$

Total useful energy is:

$$E_2 = E - E_1$$

$$E_2 = \frac{mv^2}{2} - \frac{mu_2^2}{2}$$

since

$$u_2 = v - u_1$$

$$E_2 = \frac{(2v - u_1)u_1}{2} \dot{m}$$

$$F = \frac{E_2}{u_1 T} = \frac{2v - u_1}{2} \frac{\dot{m}}{T} \quad (1)$$

$$\gamma = \frac{E_2}{E} = \frac{2vu_1 - u_1^2}{v^2} \quad (2)$$

$$P = \frac{(2v - u_1)u_1}{2} \frac{\dot{m}}{T} \quad (3)$$

These are the three general formulae which apply equally to any reaction motor, and also to rockets and jet propulsion motors.

Thermal Jet Motors

In special cases of jet propulsion motors we can assume the approximation that the quantities of air taken and exhausted are equal (the weight of fuel being only about 1/15 of the weight of the air).

The formulae can be transformed as follows:

$$E = \frac{mv^2}{2} + \frac{mu_1^2}{2}$$

$$\gamma = \frac{(2v - u_1)u_1}{2} \frac{\dot{m}_1}{\dot{m}} + \frac{2vu_1}{2} \frac{\dot{m}_1}{\dot{m}}$$

The formulae (4) (5) (6) are logically and mathematically correct, and physically true within certain limits, but they should not be used in practice. It is much simpler to include

the ram of the air into the compression in the compression-expansion type of jet motor. For the resonance type motors these formulas will give completely false results.

$$F = \frac{mv}{T} \quad (4)$$

$$\gamma = \frac{2vu_1}{v^2 + u_2^2} \quad (5)$$

$$P = vu_1 \frac{\dot{m}}{T} \quad (6)$$

The general formulae for reaction should be simplified for the so-called Athodyd (aero-thermodynamical-duct), when the speed of the propelled body is always equal to the speed of the air going through the duct.

$$v = u_1$$

$$F = \frac{u_1}{2} \frac{\dot{m}_1}{T} \quad (7)$$

$$\gamma = \frac{u_1}{v} = 1 \quad (8)$$

$$P = u_1^2 \frac{\dot{m}_1}{2T} \quad (9)$$

The mass "m" is a part of the total mass "m" of air going through the duct, and is defined by the ratio of difference between the exhaust area "A" and intake area "a" of the duct divided by exhaust area "A".

$$m_1 = m \frac{A - a}{A}$$

The air or gas, in order to fulfill this condition, should expand in the duct at the ratio of the areas of intake and

A
exhaust — ;
a

Misleading Formulae

In current publications several other formulae can be found, greatly differing from the formulae given above. We wish to discuss them separately.

The most commonly cited formulae for the external efficiency of jet motors by other authors are:

$$\eta = \frac{u_1}{v} \quad (10)$$

$$\eta = \frac{2u_1}{v} \quad (11)$$

$$\eta = \frac{2u_1}{v + u_1} \quad (12)$$

The general formula (2) for efficiency will be represented as a parabola in function of speed of the propelled body u_1 ; with the external efficiency equal to zero when $u_1=0$ and $u_1=2v$; and equal to 100% when $u_1=v$.

The formula (10) will show a straight line in function of u_1 , and the efficiency will be more than 100% for any value of u_1 bigger than v , which is against all the laws of physics. This represents a jet propulsion motor or a wonder which can generate more power than it was supplied with.

This is also true for the formulae (11) and (12).

It should be noted that the formula (10) gives the correct value for efficiency when $v=u_1$ and when

$u=0$, but this check is not sufficient and can lead to rather serious mistakes in calculation.

The application of this formula for efficiency will give the value of 50% when it should be 75%, and so on.

The formulae (11) and (12) will give even greater inaccuracies and will not conform as a mathematical expression, and cannot form the basis for any of the current experiments.

In many cases the general formulae for repulsion have been adopted to rockets and jet propulsion.

$$\eta = \frac{2vu_1 - 2u^2}{v^2} \quad (13)$$

$$P = (v - u) \frac{m}{T}$$

$$P = (v - u)u \frac{m}{T}$$

It is easy to see that they relate altogether to another type of motors, i.e. to repulsion motors, and will lead to serious mistakes when used in calculating reaction.

$$\eta = \frac{v^2 - 2u}{v^2 - u^2}$$

There the author starts from the formula for repulsion (13) and assumes that the air taken by the jet motor, which is at the speed of the propelled body u_1 , is a total loss for the external efficiency of the jet propulsion motor. Besides, starting from the wrong formula, the second assumption does not seem to be logical (Compare with formula (5)).

Atomic Powered Rockets

Energy From Atoms For Propulsive Purposes

By CEDRIC GILES

Government reports* have partially lifted the veil of secrecy on the \$2,000,000,000 research enterprise, the Manhattan Project which on July 16 conducted a successful atomic bomb test in New Mexico followed by the parachute dropping of single bombs on the Japanese cities of Hiroshima August 6, and Nagasaki three days later. The scientific achievement of splitting the atom ushers in an era where nuclear power may supplant the powder and liquid fuels now employed to propel rockets.

Atomic energy for rocket application may logically be divided into two general divisions: (1) the possibility of increasing the destructive power of the warhead; (2) the consideration of improving the propulsive energy of the fuel.

Atomic Warhead

Probably very few alterations would be necessary for adaption of the present atomic bomb to the warhead of the V-2 rocket or similar missiles. Instead of dropping the atomic bomb by parachute thereby enabling the bomb carrier to vacate the vicinity before the explosion, an atomic warhead rocket could continue on to the target. Employing the principles of radar, a radio-operated trigger could set off the explosion at a predetermined height above the ground. Exploding the remaining fuel with the bomb load, or the fuel and bomb load consisting of the same substance, are very possible.

*Atomic Energy for Military Purposes, by H. D. Smyth.

Statements relating to the Atomic Bomb, His Majesty's Stationary Office, London.

Practical Application

Atomic energy for industrial purposes will most likely be derived from safer atoms than in either the uranium or thorium series.

For conventional uses slow neutrons, traveling a few miles a second with several volts of energy, would release low-power controllable explosions. Further elimination of the danger of high-power explosions with their tremendous temperatures might be accomplished by using capsule size quantities of uranium 235, plutonium or more abundant elements. Moderators, such as paraffin, graphite, cadmium or heavy water, now used to reduce the energy of the neutron by slowing it, are applicable for shielding off the deadly radioactive rays.

Atomic Drive

Utilization of the vast energy locked in the atom as the ultimate fuel for propelling the rocket has long been considered by rocket technicians. Propulsion of the rocket will still depend on the outward expulsion of a stream of gases or minute electronic particles with the future propulsive jet very likely having greatly increased velocities and exceptionally small mass.

Atomic power may be used alone or in combination with other present fuels in the same plant. The high heat released from exploding atoms might be employed to heat liquids or gases for driving turbine units or for the expansion of the regular efflux gases. In one thermal jet propulsion system the disintegrating of a thin wire of atomic fuel fed at a controlled rate from a rotating drum would heat induced air.

(Continued on Page 20)

Motor or Engine?

On The Proper Usage Of Terms

By MARSHALL NAUL

As language is a flexible tool, and its usefulness stems in part from that property, its inexactness is at times a hindrance to the proper expression of certain things; things which naturally fall into more precise categories than the usual definitions attached to them. In such a case, a state of chaos exists until such time as definitions of the exact degree of differentiation commensurate with the prevailing usage of those terms are agreed upon. Such is the present status of the two terms, **motor** and **engine**, particularly in connection with rocketry.

Since rocketry was first seriously studied, these two words have been used interchangeably in referring to the mechanical part of the rocket which does the driving, sometimes called the **propulsor**. Of these words, **engine** is the more ancient, and until less than a century ago, it was a very general term. As extant examples of its varied uses, we have **fire-engine**, **dividing-engine**, and **cotton-gin** which is a corruption of **cotton-engine**. In the years preceding 1900, many mechanical contrivances hardly more complex than a buggy were given the elegant term **engine**. The comparatively modern word **motor** has been in vogue for the past century, but has also fallen into general misusage.

The terms **engine** and **motor** cover a definite sector in the field of machines and the prevailing method for specifying the type of engine or motor is to prefix the word most descriptive of the type. Thus we are able to recognize the essential difference between an **electric-motor** and a **tidal-motor**, and between a **diesel-engine** and a **gasoline-engine**.

The generic term for **motor** and **engine** is **prime-mover**. Now we come

to the somewhat neglected question of 'when is a **prime-mover** a **motor**, and when is it an **engine**?' A purist might consult the New English Dictionary with these results:

Engine: 'Modern usage has limited the word to the steam-engine, and to some analogous machines . . .'

Motor: 'A prime-mover, as a steam-engine . . .'

Despite the lexicographers' confusion, modern engineering usage has clearly separated the two.

The function of both **engines** and **motors** is to effect a conversion of energy from one form to another, from potential to kinetic energy. The main point of difference is that an **engine** is an energy transformer, complete in itself and requiring no independent source of potential energy to function, aside from a fuel reservoir. An engine effects in one unit the combined functions of a generator and a converter.

Distinctly different from this is the **motor** which is dependent upon an outside source of energy and is in the role of being complementary to, and dependent upon some sort of energy generator. Thus, in the case of an **electric-motor**, the outside source of potential energy is a generator in the form of a **dynamo** or a **storage-battery**. In the category of motors so defined are **tidal-motors**, **compressed-air-motors**, and so-called **solar-engines**.

This would limit the term **engine** to prime-movers of the internal-combustion type (as propulsors may be classed as internal-combustion engines), until such time as an atomic-engine is developed. In this connection, it may be mentioned that the **steam-engine** is a misnomer, and this

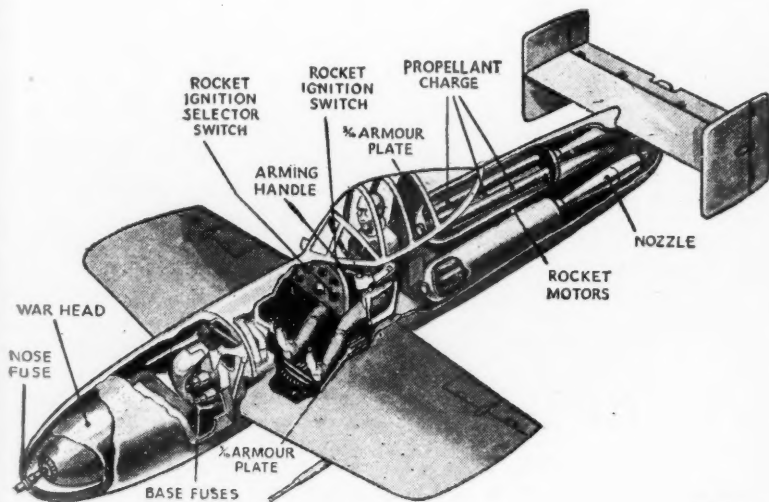
prime-mover is in reality a **steam-motor**, as it must be supplied with steam from a steam-generator in order to operate. As shown before, the meaning of the word **engine** has changed since the invention by Watts of this prime-mover.

In the field of rocket-science, which is really, as yet in an embryonic state, a certain amount of disagreement is to be expected in the nomenclature, but it would be in the interest of coherency in this field to standardize on the terminology of the rocket in a logical manner and in agreement with the terms common to other sciences. It is the purpose of the foregoing to show that the generally used term **rocket-motor** is incorrect; rather, as it falls into

the category of the internal-combustion engines as an independent energy transformer, it should be **rocket-engine**. This is not merely a matter of being precise, but rather one of correct usage. It (the rocket-engine) is not, like a **motor**, an accessory to a primary generator, but is in itself a complete power unit.

Some disagreement is also evident in referring to the prime-mover for jet-propelled machines. The prime-mover is also in this case, an engine, a **jet-engine**.

It is of interest to note that the rocket-engine shares with the athodyd the unique position of being the only prime-movers with no moving parts.



—Flight

The Japanese suicide jet-propelled bomb, the Baka, is 19 ft. 10 in. long, 3 ft. 10½ in. high, and has a 16 ft. 5 in. wing span. The high explosive war-head weighs 2,645 lbs., including 1,135 lbs. of trinitroanisole, generally used as a booster charge.

Three tail rocket motors, able to fire together or alternately, gives the Baka a horizontal flight speed of 535 m.p.h. and about 650 m.p.h. when diving. Launched from beneath a large bomber, the Baka bomb is steered by the pilot to the target.

The Station In Space

Sun Power Stations Planned By Germans

Disclosure of German war secrets found buried in mines and in the beds of rivers and lakes reveal that the Germans were contemplating the construction of solar space stations in the next 50 years. The stations, floating some 5,000 miles above the earth, were to function as an observatory, to possess a mirror, two miles in diameter, for focusing the sun's rays on earth steam-producing plants or for reflecting concentrated sunlight against hostile forces, and finally to act as a base for launching spaceships into outer regions.

The reported plans coincide so closely to proposals made on the subject in the late 20's and early 30's by Noordung, Pirquet, Orberth and others that apparently the Germans based their projects on these early theories. The terminal in space idea, which may at present appear visionary, generally takes the form of an elaborate rocket-powered plant of several sections circling the earth like a satellite at an altitude depending on its duties.

Noordung's Design

Captain Hermann Noordung, pen name of the Austrian Captain Potocnik, proposed a space station consisting of three separate units—living quarters, observatory and powerplant — connected by flexible air cables and pipelines to each other and moving in the same orbit. Placed some 22,300 miles above sea level the station was to revolve around the earth each 24 hours.

A large wheel-like structure about 100 feet in diameter, creating artificial gravity by rotating once every eight seconds, would house scientists and crew. This rotary house had rooms for every purpose located around the rim of the wheel and connected to the central airlock by elevators and stairs. All the necessities of life—light, heat,

oxygen, water and food—were provided for, with energy from the sun supplying the power requirements of the station.

Captain Noordung intended that the cylindrical spatial observatory would observe weather conditions and other happenings on the earth's surface and report all observations in detail to ground stations. Due to the absence of air and dust and the lack of weight powerful telescopes of any size could be constructed and maintained. Study of the motions, distances, magnitudes and physical constitutions of the heavenly bodies would be undertaken by learned astronomers.

The sun power plant, consisting of a parabolic mirror and engine house, was to function in a manner similar to an ordinary steam turbine system. Liquid nitrogen vaporized by the sun's rays would drive a turbine coupled to an electric dynamo for providing direct current to the different buildings. The fluid on leaving the turbine would circulate to a dark-surfaced cooling unit and be pumped back for reuse.

The Triple Station

Count Guido von Pirquet, a co-founder of an Austrian rocket society, elaborating on the plans of Noordung suggested a three-unit arrangement consisting of an inner station for observations, an outer station for landing and refueling spaceships, and a transit station for contact purposes. The first two stations would travel in circular orbits around the earth while the transit station circling in an elliptical orbit would approach within a mile of their orbits.

The approximate altitudes from the earth, length of orbits and time required for the stations to revolve around the earth are shown in the table. Speed of the transit station was

	Altitude above sea level (miles)	Length of orbits (miles)	Revolution around earth (minutes)
Inner Station	470	27000	100
Transit Station	470-3100	34000	150
Outer Station	3100	44600	200

to be three-quarters of a mile faster than the inner station as it neared the latter's orbit.

Oberth Sun Mirror

Professor Hermann Oberth was much in favor of a station for observations which every four hours circled the earth at a height of 600 miles. He also conceived of a concave sun mirror constructed of small movable facets of metallic sodium mounted on a wire network in a circular frame. Sodium, a silver-white alkaline metallic element having high reflective properties, was considered most favorable for use in the non-corrosive airless regions of space. Adjustment of the facets by electro-magnets or other means would reflect the sun's rays over a large area or concentrate the heat energy into a single beam. Construction details were minutely worked out whereby free wires attached to a rotating spaceship could be made to spread out to form a huge network upon which strips of metallic sodium would be fastened.

Suggestions for shooting the sky station to its destination, towing or propelling it by rocket power were discarded in favor of the accepted idea of transporting the space plant piece by piece by rocket ship and assembling it in space. In the weightlessness of space workmen in space suits were conceded to have no difficulty in assembling heavy sections of the station.

The proposed sun mirror was to be employed beneficially or as a devastating force. Solar energy on being directed to ground turbine stations was

to be utilized to generate steam for creating electrical power. Reflected heat would control weather, evaporate useless water and melt ice fields or illuminate large areas of the earth's surface at night.

Means for launching exploring spaceships to other planets and beyond into inter-stellar space was foreseen. Especially favorable was the suggestion of using the station as a refueling depot for spaceships ascending from the earth. The required fuel load from earth to space would be greatly reduced, as only enough fuel would need to be carried to overcome gravity from earth to the starting point for space travel.

History relates that in the siege of Syracuse, 212 B.C., Archimedes, Greek philosopher and inventor, set fire to the sails of the Roman ships by focusing the rays of the sun through newly invented burning glasses. As a weapon the Oberth reflector would also act much like a burning glass. Concentrated rays on earthly targets would turn bodies of water into steam while ships, cities and the implements of war would be burnt and destroyed.

Suggested References

Noordung, Hermann, *Das Problem der Befahrung des Weltrums* (The Problems of Space Flying). Revised English printing in *Science Wonder Stories*, 1929.

Oberth, Hermann, *Wege zur Raum-schiffahrt*, 1929.

Ley, Willy, *Rockets: The Future of Travel Beyond the Stratosphere*, 1944.

The Flying-Submersible

Its Relation To Rocket And Thermal Jet Power

By ROBERT D. WOLCOTT, Sr.

Designers have produced on paper and in blueprint form several attacks upon the problems involved in designing a flying-submersible. Whether the experiments were a success or not, a certain amount of purely scientific knowledge has been gained.

Rather than a submarine, a flying-submersible can best be visualized as an aircraft capable of withstanding the stresses and chemical reactions encountered while operating at a limited depth in water. The factor determining the operating depth is of necessity that point at which all members of the craft's structure are considered to be operative with little or no harmful reaction.

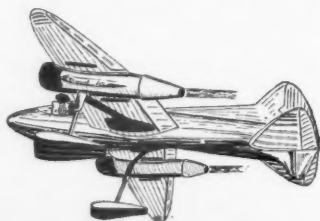
Let us consider the term "Flying-Submersible" which means only that a craft is capable of flying in air and submersion in water; no more. It would be highly unlikely that a craft embodying the proportions of a somewhat radical aircraft could travel for any great distance while submerged without prematurely exhausting its fuel supply. Therefore, let us dispense with that conception and concentrate on a craft which can maneuver for short distances under water with little applied power, retaining its fuel for airborne operation.

In the light of what has been said it should be easy to grasp the following description of a prototype flying-submersible which is briefly presented in order that the application of thermal jet and rocket power to this type of craft may be visualized.

Wadru Design

The Wadru flying-submersible was introduced to the Navy Bureau of Aeronautics in 1943 and later in a revised form to the Army Air Forces Materiel

Command; however, at the time it was designed, thermal jet had not been considered as a formidable power-plant. It was, instead, designed with two 24-cylinder Allison or two 24-cylinder Rolls-Royce internal combustion engines. Each of these engines developed approximately 2,000 h.p.



The main feature in the entire design at that time was the combined use of several known but little tested principles, one of which was a modified system of hydrofoils as originally designed by Sr. Giovanni Pegna in his PC-7, an Italian seaplane racer, which was notably different from other seaplanes of that time in that it used hydrofoils instead of pontoons.

The second notable feature of the Wadru design was the use of the airfoil fuselage designed by Vincent J. Burnelli. This design lends itself beautifully to the task of storage of fuel and cargo.

Doubtless skeptics will ask how it is possible to make a craft light enough to fly and yet strong enough to withstand the extreme contrast of pressure while submerged. The problems encountered while submerged have been solved by a method which cannot be

disclosed at this time but which are similar in some respects to the method used on the PC-7 which was capable of resting partly submerged on the water's surface. However, the PC-7 never was completely water-tight.

Since it is possible to submerge a flying-submersible, the next item of interest pertains to the welfare of the crew. A method was developed and introduced into the Wadru design whereby free air from the atmosphere was forced into the craft by means of a pump connected to an air shaft located within the periscope housing in back of the optical tube. This system was similar in many respects to the Schnorkel-Spirall system in use in German U-boats. To supplement the free air an emergency oxygen supply is provided for the sole use of the crew.

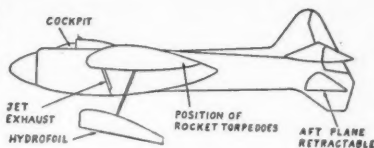
Ballast is used in much the same manner as in a submarine; by adding water to the total weight until it has reached the proper point of buoyancy.

Armaments

Since the design was very much like any other twin-engine aircraft with these chief differences, it should be easy to follow the principal differences in operation. The only evident practical use for the flying-submersible is as an instrument of warfare, primarily for the launching of torpedoes.

Torpedoes are released from their internal stowage by means of retractable launching racks which are entirely enclosed in the airfoil portion of the fuselage. They may be released in salvos of equal numbers or separate and individual rounds, the latter requiring more skill to launch because of the imminent tendency of the craft to porpoise during that type of launching.

The Wadru design has been refitted to accommodate rocket-torpedoes



which would increase the effectiveness of the craft far more than normal torpedoes.

All cannon and/or machine guns are provided with muzzle caps which prevent damage to the interior of the barrels by salt water or spray.

A radar firing mechanism was proposed for the aiming and release of the rocket torpedoes. By this means the craft could attack an enemy vessel while completely submerged and with the crew using the emergency oxygen supply.

The exact benefits and reasons for using a flying-submersible in place of a torpedo-carrying aircraft are obviously retained for military purposes.

Jet Propulsion

With the increased interest in and development of practical rocket and thermal jet units, the problem of power plants for such a craft becomes less difficult. Since rocket propulsion can undoubtedly be made to operate under water as well as in air the solution should be near at hand. When considering a form of rocket or thermal jet power one should examine the advantages of the two forms to ascertain which will be best suited to the design requirements.

The rocket form of operation involves two main factors. The first is fuel supply, the second oxygen supply. To be true rocket propulsion both must be contained within the design. The weight and space required will be great considering that there will be no means of replenishing the supply while in flight.

Thermal jet operation, however, requires only that fuel be combined with an oxygen supply derived from the atmosphere by means of a ram type intake or an impeller type compressor. Thermal jet requires less space for similar operation, as only fuel is carried, therefore an increase in the range of the craft could be effected by increasing the fuel supply as long as the increased weight is not allowed to impair the flying characteristics.

Takeoff

In applying these principles to the design of a flying-submersible one must also consider the takeoff from the subsurface or surface of the water, which will necessitate the use of rocket propulsion. A thermal jet system may be so constructed as to utilize rocket propulsion for the length of time necessary for launching the craft from the water. When sufficient altitude has been gained, thermal jet principles may be employed.

When surfaced the flying-submersible needs approximately 15 to 30 seconds to reach full power for the takeoff. With jet power almost instantaneous the rocket unit would perform the first stage of the takeoff; and when airborne enough to clear the spray and wave crests, the combined efforts of the thermal jet and rocket arrangement may be well coordinated until the thermal jet system is performing smoothly, and rocket propulsion can then be dispensed with entirely.

Concluding the presentation: one has only to look at the benefits that rocket and thermal jet propulsion provide for this application and it is easy to visualize much of the research ahead that will undoubtedly bring even better application in particular reference to the flying-submersible.

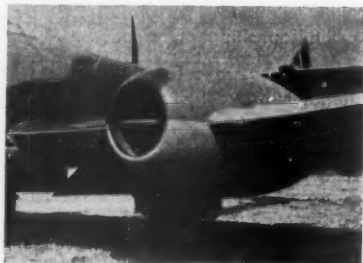
GLOSTER METEOR

The RAF Gloster Meteor, first flown experimentally in March 1943, was the first Allied jet fighter to see combat making its debut against V-1 flying bombs on August 4, 1944. The single-seat, low-wing, all metal monoplane has elliptical shaped wings with tapered edges and a high split tail plan of similar design.

Dimensions of the plane are: wing span, 43 ft., length, 41 ft., height, 13 ft., and wing area, 374 sq. ft. Powered by two Rolls-Royce Welland or Derwent jet engines, development of the Whittle basic design, the Meteor does over 450 m.p.h. The centrifugal-compressor turbo-jet units are placed on either side of the fuselage.

Servicing of the plane is made most convenient by the specially designed retractable low tricycle undercarriage. With the main wheels installed between engines and fuselage and a nose wheel the tail is raised high. Armament consists of a camera gun which may be used separately or linked with the four 20 mm. Hispano nose guns.

The Meteor is reported to have a high maneuverability, with an absence of vibration and noise in flight and a not too high landing speed.



—British Official Photograph

Close-up of the nacelle of the port power unit of the Meteor jet fighter.

ROCKETRY NEWS

American-British Penetration Bomb

U. S. 8th Air Force Flying Fortresses employed jet-propelled bombs on February 10 and again on March 14 of this year against E-boat pens at IJmuiden, Holland. The British-American newly developed bomb, after being dropped in the usual manner, travels downward at speeds greater than sound (1,100 f.p.s. at sea level). Fused to explode after deep penetration, the rocket-propelled bomb creates a minor earthquake in the vicinity.

3,000-Mile Rocket Bomb

German records disclose that the V-2 long range rocket, which was first successfully tested on October 3, 1942, was a product of the drawing boards of 1940. One winged version of the V-2 was reported to have a range of 300 miles, with a later model to reach 1,800 miles.

At the end of the war specifications for production of accurate 3,000-mile range V-2 rockets were being drawn up, with German scientists contemplating in two years time the development of rockets extending the horizontal distance to 15,000 miles. Also under consideration was the application of these rockets for commercial use in carrying mail and passengers.

Underwater Rockets

Experiments on rockets fired at air-planes or coastal cities from submerged submarines of advance design were underway in the Toeplitz Sea, an Austrian Alps lake, at the war's end by German experts under the direction of a Dr. Heinrich Determann. Apparatus and methods had been successfully developed enabling the firing of rockets from 300 feet underwater.

V-2 For Cosmic Ray Study

Plans have been perfected by Alexander Dauvilliers, French professor of physics, for employing the V-2 rocket for the study of cosmic rays and other

radiations. Taking off from an especially constructed launching ramp at the Observatoire du Pic du Midi, the rocket would carry instruments for recording cosmic ray data in its ascent at 2,000 m.p.h. through the stratosphere and return to the earth.

Jet-Driven Unicycle

A jet-propelled one-wheel vehicle, developed by Lt. Robert Morgan, British naval pilot, is expected to attain speeds of 520 m.p.h. Powered by a liquid gas, the Bomb, as the car is called, is slated for attacks on present land speed records.

The 12-foot single wheel, within which the driver sits, will be covered by a glass and steel streamlined, pear-shaped body 15 feet high and 25 feet long. Rear stabilizing fins come into action after two small wheels for holding the machine upright at the start are discarded.

Jet Plane Races

One of the attractions in next year's national air races will be a race for jet-propelled planes. The Weatherhead Company at Cleveland has donated a trophy for the event to foster continued development in the field of jet propulsion.

Atomic Bomb Metal

Carboloy cemented carbide, the hardest metal created by science, was used in the atomic bomb. Made of powdered tungsten carbide and cobalt placed under high pressures and temperatures, the metal weighs 50 per cent more than lead.

Ryan Fireball

The Navy's new fighter plane, the Ryan Fr (Fireball), is both propeller and jet driven. The front Wright Cyclone engine gives a speed of 320 m.p.h. to the Fireball while the rear General Electric thermal jet engine drives the plane at 300 miles an hour. Top speed of the highly maneuverable, fast-climbing plane is withheld.

Dr. Robert H. Goddard

A Biographical Note

Robert Hutchings Goddard was born in Worcester, Mass., on October 5, 1882. His early schooling was obtained at Boston, where he lived with his family until he was sixteen, and his college work at Worcester, where he was graduated from the Worcester Polytechnic Institute in 1908.

Upon graduation, he obtained a position at Worcester Polytechnic Institute as an instructor in physics. He continued to be connected with the academic world until 1934, part of the time on leaves of absence. His teaching career was convention, rising in the usual steps from instructor to assistant professor and finally to full professor at Clark University. During a small part of this period, in the 1912-1913 season, he served as research fellow at Princeton University. The rest of his academic career was passed in Worcester.

In his school days Goddard enjoyed mathematics, and was fond of studying better ways to do things. In his freshman year at college one of his professors assigned the topic "Traveling in 1950" as a theme subject. Goddard produced a bold paper in which he described in detail a railway line between Boston and New York, in which the cars were run in an evacuated tube and were prevented from metal-to-metal contact with the guide rails by electromagnets. With such a "vacuum railroad" he calculated it would be possible to make the run from New York to Boston in ten minutes.

As a young professor of physics, Goddard made contributions of importance on the conduction of electricity from powders, the development of crystal rectifiers, the balancing of airplanes, and the production of gases by electrical discharges in vacuum tubes. During his fellowship in

Princeton, he produced the first laboratory demonstration of mechanical force from a "displacement current" in a magnetic field; this current being the fundamental concept in Maxwell's theory of electromagnetic waves (radio).

These achievements, however, were merely tune-ups for the real accomplishments of his life, which were soon to begin. There is no record of the first experiments he made with rockets, though it is known that this work began as part of a search for practical means of sending meteorological instruments into the stratosphere. To friends, Dr. Goddard once described with amusement some static tests he made as early as 1908 with small rockets in the basement of Worcester Polytechnic Institute. His experiments filled the basement of the building with acrid smoke, and so disturbed the equanimity of the institution he was asked to desist, at least until better equipment could be provided.

It was during his brief period at Princeton in 1912 that he made the initial computations which later were to form the basis of the Smithsonian paper of 1919. In this period, when he was about thirty, the great excitement of discovery first began to come upon him, for his calculations clearly indicated that only a little fuel, relatively, would be required to lift a payload to really great heights by rocket power, provided the rocket was so constructed as to make use of the fuel effectively.

Upon returning to Clark, in 1914, he began to experiment in earnest, beginning with ship rockets, and continuing with rockets of various types manufactured by himself. By 1916 he had reached the limit of what he could do on his own resources. Inexperienced though he was in the ways of money-raising for scientific research,

his earnestness and enthusiasm won respect and attention. When he presented his idea on paper to the Smithsonian Institution that year he promptly received a letter from Dr. Charles D. Walcott, then secretary of the Institution, commending him on the report and inquiring how much money would be needed.

Goddard guessed it would require \$10,000, but cautiously asked for \$5,000. Between that day in 1916 and the appearance of his first paper in 1919, the experimental work required a total of \$11,000, the whole sum of which was made available by the Smithsonian. This was the investment that launched modern rocketry and jet propulsion.

The rest of Goddard's achievements are told, factually, in his two reports. What is not disclosed—what can never adequately be told—is the labor and persistence and thought and heart-break that went into these accomplishments, through which Goddard fathered all the research and development which led to the great expansion of jet propulsion in World War II; which continues to grow and unfold today in the jet propulsion research achievements of peace.

In 1924 Goddard married Esther Christine Kisk, who had been associated with him in his work, and who continued after their marriage to play a large part in the continuance of his research. He frequently ascribed to her the courage and faith which made his continuing efforts possible. Among other things, she was the official photographer of his tests. It was her camera that produced the pictures which illustrate his two reports.

After the entry of the United States into the first World War in 1917, Goddard volunteered his services, and was set to the task of exploring the military possibilities of rockets. He succeeded in developing a trajectory rocket which fired intermittently, the

charges being injected into the combustion chamber by a method similar to that of the repeating rifle. He also developed several types of projectile rockets intended to be fired at tanks or other military objectives, from a launching tube held in the hands and steadied by two short legs, a device similar in many respects to the "bazooka" of World War II.

These weapons were demonstrated at the Aberdeen Proving Grounds on November 10, 1918, before representatives of the Signal Corps, the Air Corps, the Army Ordnance and others. The demonstrations went off quite successfully, but the Armistice next day put an end to the war and also to the experiments.

In the Second World War Goddard likewise volunteered his services, and was engaged in work on liquid fuel rocket research for the Navy at Annapolis throughout the conflict.

Goddard concluded his last report, in 1936, with these words: "The next step in the development of the liquid-propellant rocket is the reduction of weight to a minimum. Some progress along this line has already been made."

Part of this progress consisted of the development of ingenious, light-weight, simple fuel pumps for injecting the propellants rapidly into the liquid-fuel rocket motor. The physicist had expected to return to New Mexico as soon as possible after the War, to continue his work on high altitude rockets, and planned to set some altitude records which would have been spectacular indeed. His death, at the age of 62, brought this program to an untimely end. Nevertheless, Goddard lived to see the dream of his youth become reality. Jet propulsion, for the uses of war at least, matured in his lifetime from a fantastic notion into a billion-dollar industry. It gave promise,

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Society Notes

An Appreciation

Dr. Robert H. Goddard, who was for many years a member of the American Rocket Society and at his death was a member of its Board of Directors, was the first scientist to apply modern technical methods to the investigation of rockets and jet propulsion, and literally was the father of all the research and development which has led to the great expansion of jet propulsion in all its forms.

He was universally beloved and respected, and especially so by his associates in research on rockets and jet propulsion. The Board of Directors recently paid tribute to him in these words:

"With the death on August 10, 1945, of Dr. Robert H. Goddard, American science has lost one of its greatest pioneers—the creator of the modern science of rocketry.

"His investigations covered almost every essential principle involved in both the theory and practice of high-power rockets, and were mainly responsible for the immense progress of the subject in the last three decades, which has exceeded in importance the results previously attained in several centuries of early development.

"His inventions included the first liquid fuel rocket, the first smokeless powder rocket, the first practical automatic steering device for rockets, and innumerable other devices. He was one of the first to develop a general theory of rocket action, including the important "optimum velocity" principle, and to prove experimentally the efficiency of rocket propulsion in a vacuum.

"Even more impressive than Dr. Goddard's technical skill and ingenuity was his extraordinary perseverance, patience and courage in carrying on his investigations in the teeth of public

skepticism and indifference, with limited financial resources, and in spite of heartbreaking technical difficulties—a combination of obstacles which might have baffled and disheartened a less stout-hearted pioneer. Almost single-handed, Dr. Goddard developed rocketry from a vague dream to one of the most significant branches of modern engineering.

"The lifework of Dr. Goddard, as both a scientist and a man, will always remain a brilliant inspiration to all of those who are privileged to carry on his endeavors, and to every other bold explorer on the new frontiers of science. In time to come, his name will be set among the foremost of American technical pioneers."

SOCIETY'S OFFICERS

James H. Wyld, research engineer for Reaction Motors and designer of the Wyld regenerative motor, one of the first practical liquid fuel motors, has been re-elected President of the American Rocket Society. A pioneer experimenter, Mr. Wyld is a long-time member of the Society's Experimental Committee.

John Shesta, chief engineer of Reaction Motors, Inc., long-time member of the Society's Experimental Committee and formerly its Chairman, a pioneer experimenter and designer of one of the first liquid fuel rockets to reach the speed of sound, was elected Vice-President of the Society.

G. Edward Pendray, private counselor in management, public relations and education, formerly President of the Society, and at one time Editor of *Astronautics*, was re-elected Secretary. Pioneer experimenter and co-designer with H. F. Pierce of the Society's first liquid fuel motor and first liquid fuel rocket, Mr. Pendray is author of "The Coming Age of Rocket Power."

Dr. Samuel Lichtenstein, a member of the Society almost since its founding and long a member of the Board of Directors, was re-elected Treasurer of the Society.

Cedric Giles, former President of the Society, and a member of the Board of Directors, was re-elected Editor of the Journal of the American Rocket Society. Mr. Giles, long interested in rocket experimentation and long-time member of the Society, is employed by the New York Telephone Company.

Lovell Lawrence, Jr., former Secretary of the Society, a pioneer experimenter in rockets in this country, specialist in electronics, and now President of Reaction Motors, Inc., was named Chairman of the Program Committee.

H. F. Pierce, former President of the Society and pioneer experimenter, co-designer of the Society's first liquid fuel rocket and motor, former member of the Society's Experimental Committee, now a member of the staff of Reaction Motors, Inc., was elected Chairman of the Nominations Committee.

MEMBERS

The following alphabetical list of members are enrolled in the Active grade of membership of the Society. From time to time the JOURNAL will list the names of members in this and other grades of membership.

Alfred Africano, Cumberland, Md.
Col. A. A. Albahr, Los Angeles, Calif.
Russell T. Anderson, Denver, Colo.
Roy Price Barker, New York, N. Y.
David D. Beach, Ft. Lauderdale, Fla.
Murray C. Beebe, Jr., Glastonbury, Conn.
Martin R. Benjamin, Kew Gardens, N. Y.
Capt. Fred Bertino, New York, N. Y.
Alfred H. Best, Irvington, N. J.
Karl Leo Braun, Jr., Springfield, Ohio.
Robert J. Bremner, Southampton, Hants, England.

Louis Bruchiss, New York, N. Y.
Eric Burgess, Denton, Manchester, Eng.
Frank R. Canning, East Orange, N. J.
W. Hodge Caraway, Berkeley, Calif.
J. O. Chesley, Pittsburg, Pa.
Joseph Karel Chmel, Toronto, Canada.
Alexander P. de Seversky, New York, N. Y.
Ens. Herbert F. Duquette, Jr., New York, N. Y.
Zygmunt Fonberg, New York, N. Y.
Edward M. Foote, Jr., New Rochelle, N. Y.
Edward E. Francisco, Jr., Little Falls, N. J.
Fred M. Garland, Pittsburg, Pa.
Cedric Giles, Brooklyn, N. Y.
L. Michael Grieco, Baltimore, Md.
Leonard A. Guaraldi, Somerville, Mass.
Joseph Haaga, Astoria, N. Y.
Wm. S. H. Hamilton, Larchmont, N. Y.
Charles Marshall Hayes, Terre Haute, Ind.
Roy Healy, Dover, Del.
Edmund J. Henke, Chicago, Ill.
William S. Holloway, Honolulu, T. H.
Robert H. Hunter, Cleveland, Ohio.
Nicholas Ivanovic, Philadelphia, Pa.
Hugh D. Ivey, Atlanta, Ga.
Ens. E. P. Killian, Little Creek, Va.
Dr. Alexander Klemin, Greenwich, Conn.
Richard E. Knight, Bridgeport, Conn.
Max Krauss, New York, N. Y.
Dr. M. Z. Krzywoblocki, Providence, R. I.
Joseph E. Kucher, Lyndhurst, N. J.
Lovell Lawrence, Jr., Pompton Lakes, N. J.
Constantin P. Lent, New York, N. Y.
Sgt. John F. Lewis, New York, N. Y.
Dr. Samuel Lichtenstein, New York, N. Y.
Charles C. Littell, Jr., Piqua, Ohio.
Prof. Arthur A. Locke, Detroit, Mich.
Laurence E. Manning, New York, N. Y.
Jacques Martial, New York, N. Y.
Mrs. Jean Mater, Summit, N. J.
Capt. Milton H. Mater, New York, N. Y.
T. Melville-Ross, Sussex, England.
Robert Earl Meyer, Parris Island, S. C.
Lee V. Mincemoyer, Philadelphia, Pa.

Li. C. B. Moore, Jr., Spring Lake, N. I.
A. L. Murphy, St. Petersburg, Fla.
Mrs. Clayton C. McCauley, San Francisco, Calif.

John F. McLeod, Jacksonville, Fla.
David E. Pearsall, Avon, Conn.
G. Edward Pendray, Crestwood, N. Y.
J. J. Pesqueira, New York, N. Y.
H. Franklin Pierce, Fairlawn, N. J.
William C. Rohrer, Redlands, Calif.
Nathan Schachner, Bronx, N. Y.
W. A. Semion, Los Angeles, Calif.
John Shesta, North Arlington, N. J.
George V. Slotman, New York, N. Y.
Donald Smith, Farmingdale, N. Y.
Leo E. Supina, Stafford Springs, Conn.
Leslie Velossy, New York, N. Y.
William A. Villevock, Cleveland, Ohio.
Michael T. Vincek, Clifton, N. J.
Herbert James Webb, Pittsburg, Pa.
James N. Wheeler, Sea Cliff, N. Y.
Malcolm J. White, Berkeley, Calif.
Cpl. R. D. Wolcott, New York, N. Y.
Albert V. Works, Jr., Dallas, Texas.
James H. Wyld, Pompton Lakes, N. J.

ROCKET SOCIETIES

Georgia School of Technology Rocket Society

The Georgia School of Technology Rocket Society, Atlanta, Georgia, was formed on April 3, 1945 by Harold J. Mason, the present president and a member of the A.R.S. The Society which has a membership of fifty, is holding meetings and collecting reports on rocket subjects for future publication.

Combined British Astronautical Society

The June-August issue of the Official Bulletin of the Combined British Astronautical Society states that on August 25 a London Branch of the C.B.A.S. was formed at Birkbeck College, London. The two other divisions of the C.B.A.S. are the Astronautical Development Society (Southern Counties) and the Manchester Astronautical Association (Northern Counties).

British Interplanetary Society

An informal meeting of the non-active British Interplanetary Society was held last June to consider the possibility of restoring the Society to full activity. An emergency committee, consisting of Prof. A. M. Low, P. E. Cleator and others, was appointed to reorganize and incorporate the Society.

Melbourne University Interplanetary Society

Formation of the Melbourne University Interplanetary Society, Melbourne, Australia, took place the beginning of this year. The present president is Dr. H. C. Corben, author of papers on theoretical quantum mechanics, and the secretary is S. N. Milford.

Glendale Rocket Society

Discussion on the experimental program constitutes the greater part of the meetings of the Glendale Rocket Society, Glendale, Calif. The Society's officers are: President, George James; Vice-President, Richard Reiss; Secretary-Treasurer, Robert Stucker; Director of Research, Lee Rosenthal.

Springfield Society for Rocket Experimentation

After a period of inactivity due to the war, the Springfield Society for Rocket Experimentation, Springfield, Ohio, is again contemplating an active program. Officers of the Society are: President, Karl Braun; Vice-President, Francis Ruzsa; Secretary, Richard Snodgrass.

Australian Rocket Society

The former president of the Australian Rocket Society, J. A. Georges, is reorganizing the Society, which became disjoined during the war, and has a postwar program in preparation. A change of name is contemplated with the replacing of the word "Rocket" with "Astronauts".

BOOK REVIEWS

Raketenflugtechnik (Rocket Flight Technique), by Eugen Sanger. Verlag von R. Oldenbourg, Berlin, 1933. Published and distributed in the public interest by authority of the Alien Property Custodian by Edwards Brothers, Inc., Ann Arbor, Mich., 1945; 222 pages, \$5.00.

A reprint of the German technical work on the many experiments conducted by a teacher of aerodynamics at the Technical High School of Vienna. The first part considers rocket propulsion in relation to properties of various fuels, the second discusses aerodynamic problems and the third section deals with trajectories of rockets and rocket planes flying at supersonic speeds. Valuable information is given on rocket motors with extra long exhaust nozzles and in numerous tables on combinations of fuels and oxygen-carriers. The book is well illustrated with drawings and is indexed.

Wege zur Raumschiffahrt (Way to Space Travel), by Hermann Oberth. Verlag von R. Oldenbourg, Berlin, 1929. Published and distributed in the public interest by authority of the Alien Property Custodian by Edwards Brothers, Inc., Ann Arbor, Mich., 1945; 431 pages, \$8.00.

Reprint of the greatly enlarged third edition of the original 1923 German booklet "Die Rakete zu den Planetenräumen" (The Rocket into Interplanetary Space) which helped to inspire the German authoress Thea von Harbou to write a manuscript for the film "Frau im Mond" (The Girl in the Moon). The third edition was awarded the 1928 REP-Hirsch Interplanetary Prize of 500-francs which was doubled in value.

Starting with the four assertions—

the building of space machines, the ability to attain escape velocity, the carrying of personnel and the possibilities of future development — the author mathematically treats each in turn. The theoretical classic also contains advanced mathematical calculations on the problem of fuels, types of rocket motors, step-rockets, and a solar space mirror to reflect the sun's rays to the earth. Numerous drawings, graphs, tables, four plates and an index supplement the text.

Rockets. Official Publication of the United States Rocket Society, Inc. Vol. 1, No. 1, May 1945; 32 pages, \$4.00 yearly.

This first quarterly issue, of a Society mainly concerned with interplanetary travel, emphasizes the earth to moon proposition. Feature articles deal with the V-1 robot bomb, conditions on the moon, and an excerpt of a talk on moon rockets. Other items refer to an analysis of rocket control, rocket stamps, planet reference tables, book reviews and society notes. A number of illustrations are included to clarify the text.

Astro-Jet, Journal of the Glendale Rocket Society. No. 10, July 1945; 10 pages. \$1.00 per year.

Appearing in printed form the publication shows a marked improvement over previous issues. An account of the 1936 rocket mail flight from McAllen, Texas to Reynosa, Mexico is given, followed by articles on determining the combustion efficiency of black powder charges by weighing and computing the percent of ash, and calculations on a rocket flight test of a sighting device system. A number of society ground tests and flights are also recorded.

BOOK REVIEWS

Theory and Testing of Jet Propulsion Motors and Rockets, by Zygmunt Fongberg. Aircraft Jet and Rocket Corporation, New York, 1945; 82 pages, \$2.00.

A booklet developed from a paper on the theory of reaction propulsion and methods of testing jet propulsion motors. Theory and thermodynamics of reaction motors are discussed with illustrative examples showing the practical application of formulas and definitions to the solution of problems. Various types of jet motors are considered with chapters on the rocket motor, the compression-expansion type, the resonance type, the athodyd, and thrust amplifiers.

The static thrust, rotational, wind tunnel, and pendulum types of test stands are described and test examples are mathematically computed. Velocity and efficiency tables and graphs, and drawings of reaction motors and test stands are included.

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too, of achieving also the objectives of peacetime research for which he had spent a lifetime of thought and effort.

Dr. Goddard had been a member of the American Rocket Society for many years, and a few months before his death on August 10, 1945 at Baltimore, Md., was elected to the Society's Board of Directors. In a public statement the Board of Directors pointed out that "American science has lost one of its greatest pioneers — the creator of the modern science of rocketry."

—G. E. P.

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Concentrating a beam of electrons on drops of water would immediately split them into oxygen and hydrogen atoms which on uniting would form steam to drive turbines. Ships could use sea water, while the necessary large tank of water carried by land vehicles and aircraft under favorable conditions might be augmented by condensing moisture from the atmosphere.

Electronic Control

Attaching light compact atomic jet producers to cross-arms on a revolving shaft will provide a source of power. A number of adjustable disintegrator projectors would permit directional control of the rocket by varying the intensity of the propulsive energy of the bombarded material.

An electronic rocket steered by electrostatic or magnetic fields produced as a by-product of the atomic energy, or electrical or mechanical units operated by atomic power within the rocket have been suggested.

In the atomic age is the reality of atomic-propelled spaceships carrying a negligible fuel load and having the necessary power output for limitless range and high velocities. With atomic drive passenger travel in the stratosphere, stations in space, and interplanetary communications become a fact.

Recommended References

Pendray, G. Edward, "Rocket Power From Atoms?" *Astronautics*, No. 45, April 1940.

Sternberg, Robert L., "Electronic Space Rocket," *Astronautics*, No. 57, March 1944.

Cleaver, A. V., "Bombers or Rockets?" *Flight*, September 6, 1945.